



Recent Advances in Cholesterol Lowering Probiotics: From Mechanism to Clinical Applications: A Review

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10.18805/ajdfr.DR-2372

ABSTRACT

Anomalies of various cholesterol lipoprotein lipids are associated with the coronary heart disease. The probiotic microorganisms has special ability to produce short-chain fatty acids (SCFAs) thereby reduce the risk of hypercholesterolemia. In the present review, various risk factors and cholesterol associated disease along with their available treatment was elucidate. The important role and mechanism of action of the probiotics in healthy improvement and cholesterol lowering were described in detailed. A good probiotics have resistance to bile toxicity and gastric acidity and adhere to gut epithelial tissue. It also involved in the modulation of immune responses and ability to influence metabolic activities. Production of SCFAs are increase by probiotics and this intern activated by peroxisome-activated proliferator bindings. These SCFAs inhibits enzyme reaction in liver results in cholesterol synthesis inhibition. Increase utilization different type of microbes for the probiotics due to increase in the microbial research for newly discovered and identified microbota and which could be used for probiotics. Authorization of select probiotic products as functional foods has opened avenues for their use in dietary interventions aimed at cardiovascular risk reduction.

Key words: Cholesterol, Hypercholesterolemia, Microorganism, Probiotics.

Although cholesterol is an essential lipophilic component of the body tissue, impaired levels of the blood cholesterol are a leading cause of coronary heart diseases (CHD) (WHO 2009; Kumar *et al.*, 2012). As per WHO and NCD Risk Factor Collaboration study, CHD has a leading cause of death and it will affects approximately 23.6 million people around the world by 2030 (Yusuf *et al.*, 2004). Earlier studies reported that, hypercholesterolemia contributes incidences of heart attack around 45% in the Western Europe and 35% in Central and Eastern Europe (Ibrahim *et al.*, 2023). However, dietary intake along with behavioral parameters regular exercise and drug therapy is changing blood cholesterol pattern rapidly throughout the world (Murray *et al.*, 2020). Pharmacological therapies are effectively lowering blood cholesterol levels are available for the management of high blood cholesterol; however, they are increasing cost burden and are known to have adverse side effects (Feingold, 2024).

Lipid abnormality

Anomalies of various cholesterol lipoprotein lipids are associated with the coronary heart disease. These abnormalities such as high levels of total cholesterol, very low and low density lipoprotein along with low levels of high density lipoprotein (HDL) cholesterol are major risk factors for coronary heart disease. A strong pathophysiological association was found between increased level of low density lipoprotein (LDL) and initiation and progression of coronary atherosclerosis (Gaggini *et al.*, 2022). Lowering the raised parameters of lipid abnormality leads towards revert and stabilize atherosclerotic vascular disease (Linton *et al.*, 2019). The normal values of lipid abnormality are depicted in the (Table 1).

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How to cite this article: Bochgire, M., Jadhav, A. and Mandave, P. (2025). Recent Advances in Cholesterol Lowering Probiotics: From Mechanism to Clinical Applications: A Review. *Asian Journal of Dairy and Food Research*. 1-10. doi: 10.18805/ajdfr.DR-2372.

Submitted: 04-07-2025 **Accepted:** 03-09-2025 **Online:** 17-10-2025

Causes of the dyslipidemia include hypothyroidism, poorly diabetes control, renal disease, alcohol habits and a numerous of prescribed drugs (Rygiel *et al.*, 2018). However, several drugs are being considered as culprit for this impairment include oral beta blockers, protease inhibitors, estrogens, glucocorticoids, bile acid binding resins, retinoids, thiazide diuretics and antipsychotics. Other cause like obesity along with high carbohydrate diets may leads to increase triglycerides. Hypothyroidism is also one of the causes of elevated LDL cholesterol and other secondary cause includes, obstructive liver disease, nephrotic syndrome. Secondary causes of low HDL cholesterol include the use of anabolic steroids and retinoids (Johnson and Semenkovich, 2011).

Obesity also has considerably increased in recent decades. According to Djalalinia *et al.* (2021) study, obese

persons are developing 2.8 times more risk for the dyslipidemia than normal-weight individuals. The study warns about the upcoming burden of lipid abnormality in near future. The higher carbohydrate along with low fat intake is associated with lower apolipoprotein A1 and HDL and higher triglycerides level.

Lipid abnormality prevalence

A study conducted by Anjana *et al.*, (2023), reported urban and rural residents population of 31 states and union territories of India for prevalence of dysglycaemia, hypertension, generalized obesity, abdominal obesity and dyslipidaemia using a stratified multistage sampling design. Around more than 1.19 lakhs individuals were studied. Dyslipidaemia were common in every fifth participants.

Dyslipidemia is found to be prevalent in obese individuals (88.1%), which are residents of urban areas (81.1%), in those with sedentary lifestyle along with physical inactivity (83.3%) and diabetic individuals (91.4%) and hypertension (86.6%). People with a coronary heart diseases history also exhibited higher prevalence (86.4%) for dyslipidemia. The dyslipidemia prevalence is higher in patients with a history of stroke (85.9%). Those with family history of cardiovascular diseases also showed slightly higher dyslipidemic prevalence (Khanali *et al.*, 2023).

The dyslipidemia prevalence is high across the world; however, it was in accordance with the previous national reports and the MASHAD prospective cohort study (Hedayatnia *et al.*, 2020). It was 79% in India (Joshi *et al.*, 2014), 78.7% in Turkey (Bayram *et al.*, 2014), 75.7% in Jordan (Khader *et al.*, 2010) and 62.1% in northeastern China (Zhang *et al.*, 2017) with consistent low HDL-C. This prevalence may be due to physical inactivity, high carbohydrate intake and obesity. The physical inactivity was reported in 51.3% of the Iranian population (Nejadghaderi *et al.*, 2021). Cholesterol risk factors and its associated abnormalities are showed Fig 1.

Available treatments for lowering abnormal lipid profiles

The available treatments were drug based therapies are very few and have side effects. Life style modifications

such as eating a balanced diet and exercise were also known to have lipid lowering effect (Dybiec *et al.*, 2023). Statins [atorvastatin (Lipitor®), rosuvastatin (Crestor®), pitavastatin (Livalo®) and simvastatin (Zocor®)] effectively blocks enzymes which produces the cholesterol in liver. The drugs are involved in the lowering mechanism of increased LDL and triglycerides. Already deposited cholesterol / plaque of the arteries get reduced. It stabilized the plaque formation mechanism and further complications associated with the lipid abnormality. However, the prolong use of statins may associated with muscle pain, gastrointestinal discomfort, rarely liver damage. Other than the statin treatment, other categories of drugs were also recommended (Sizar *et al.*, 2023). These are listed below.

Cholesterol absorption inhibitors

Cholesterol absorption inhibitors, such as ezetimibe, it helps to lower the amount of cholesterol absorption in the body from consumed food. The medication prescribed once in a day and it exhibits few side effects, such as, diarrhea and abdominal pain (Sizar *et al.*, 2023).

Table 1: Criteria for clinical diagnosis of the abnormal lipid profile.

Parameters	Normal range (mg/dL)
Total cholesterol	< 200
Triglycerides	< 100
Low density lipoprotein	<150
High density lipoprotein	> 40
Apolipoprotein A	≥ 120 in Male and ≥140 in female
Apolipoprotein B	< 90
Apolipoprotein B/A1 ratio	Lower Risk: <0.7 in male and <0.6 in female Average Risk: 0.7-0.9 in male and 0.6-0.8 in female Higher Risk: >0.9 in male and <0.8 in female

The values are adopted from Third Report of the National Cholesterol Education Program (2002).

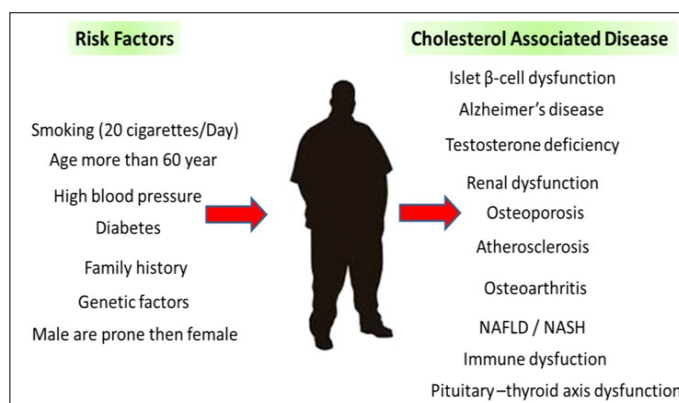


Fig 1: Cholesterol risk factors and its associated abnormalities.

Fibrates

Fibrates intended to lower down the synthesis of triglycerides. It may help to increase in HDL level. Fibrates are taken daily. It shows some common side effects such as gastrointestinal upset, including nausea, diarrhea and vomiting (Getto *et al.*, 2011).

Bile acid resins

Bile acid resins binds to bile acid in intestine. Bile acid contains cholesterol. Binding with resins prevents its absorption from blood. They have been prescribed for decades. The most common side effect is gastrointestinal discomfort.

Comorbidities such as hypertension, diabetes, chronic kidney disease, hypothyroidism, or liver disease are associated with high risk of cardiovascular disease and lipid levels (Hunter and Hegele, 2017). Prevention of lipid abnormality is crucial to improve the quality of life and reduce the risk of cardiovascular complications. Individuals with family history or have known risk factors, are recommended to screen for lipid abnormality regularly. Food enriched with omega-3 fatty acids from nuts, fish and seeds; whole grains; healthy fats; lean proteins and fresh fruits and vegetables help to maintain the nutrient balance in the body. All the above mentioned treatment regimens are associated with certain side effect if used long term. The healthy, safe without side effect treatment or intervention is needed to be inculcated in the life as a preventive and / or therapeutic measure. One of such approach is use of probiotics as a food supplement.

Additions of probiotics in the diet was reported to improve cholesterol lowering and lipid normalizing effect.

Probiotics and its health benefits

Probiotics are the sources of good microbes that may exert beneficial effects on the body by improving balance of the gut microbial (GM) flora (Pandey *et al.*, 2015). Several recent studies show that, improvement in the GM through probiotics may lead to prevent and manage the metabolic syndrome (He and Shi, 2017). As they modulate colon microbiota and immunogenic responses in the gut, which ultimately result in health improvement. Several strategies are being utilized for probiotics supplementation, one of the common is oral ingestion of probiotic which has been used to maintain GM to fight metabolic syndrome (Wang *et al.*, 2015, 2020). Different sources of probiotics are available such as yoghurt, Greek yoghurt, smoothies, etc (Momin *et al.*, 2023). *Lactobacillus* and *Bifidobacteria* are the most commonly utilized bacteria and exert useful probiotic effects (Elango, 2025; Tom-Dieck *et al.*, 2021). Studies have associated these two genera with human gut health and metabolic functions (Bernini *et al.*, 2016). *Pediococcus pentosaceus* is known to have various probiotic effects such as cholesterol-lowering, antioxidant properties and immune effects (Qi *et al.*, 2021). Probiotics is the source of living strains of bacteria that add to the population of good bacteria in the intestine, are promoted by prebiotics, specialized plant fibers that serve as food for

Table 2: Commonly used species as a probiotics.

Organism class	Genera	Species	Ref.
Bacteria	<i>Lactobacillus</i>	<i>Acidophilus</i> , <i>sporogenes</i> , <i>plantarum</i> , <i>rhamnosum</i> , <i>delbrueck</i> , <i>reuteri</i> , <i>fermentum</i> , <i>lactus</i> , <i>cellobiosus</i> , <i>brevis</i> , <i>casei</i> , <i>faracinis</i> , <i>paracasei</i> , <i>gasseri</i> , <i>crispatus</i>	Cammarota <i>et al.</i> , 2009; Soni <i>et al.</i> , 2021
	<i>Bifidobacterium</i>	<i>Bifidum</i> , <i>infantis</i> , <i>adolescentis</i> , <i>longum</i> , <i>thermophilum</i> , <i>breve</i> , <i>lactis</i> , <i>animalis</i>	Pawar <i>et al.</i> , 2022
	<i>Streptococcus</i>	<i>lactis</i> , <i>cremoris</i> , <i>alivarius</i> , <i>intermedius</i> , <i>thermophilis</i> , <i>diacetylactis</i> , <i>epidermidis</i> , <i>hyicus</i> ssp. <i>Hyicus</i> , <i>aureus</i>	Kok <i>et al.</i> , 1995
	<i>Leuconostoc</i>	<i>Leuconostoc Mesenteroides</i> ; <i>Leuconostoc citreum</i>	Muthusamy <i>et al.</i> , 2023
	<i>Pediococcus</i>	<i>Pediococcus pentosaceus</i>	Montemurro <i>et al.</i> , 2020; Qi <i>et al.</i> , 2021; Xu <i>et al.</i> , 2021
	<i>Propionibacterium</i>	<i>Propionibacterium</i> sp.	Bhatia <i>et al.</i> , 2004
	<i>Bacillus</i>	<i>Bacillus subtilis</i>	Cammarota <i>et al.</i> , 2009
	<i>Enterococcus</i>	<i>E. faecium</i> and <i>E. faecalis</i>	Im <i>et al.</i> , 2023
	<i>Acinetobacter</i>	<i>calcoaceticus</i>	Kok <i>et al.</i> , 1995
	<i>Saccharomyces</i>	<i>Cerevisiae</i> , <i>boulardii</i>	Hawrelak, 2003
Yeast and molds	<i>Aspergillus</i>	<i>niger</i> , <i>oryzue</i>	Sharma <i>et al.</i> , 2022
	<i>Sacaromyces</i>	<i>boulardii</i>	Kelesidis and Pothoulakis, 2012

probiotics. Some commonly used bacteria, yeast or mold species are given in the Table 2.

Increase in utilization of different type of microbes for the probiotics due to increase in the microbial research for newly discovered and identified microbota and which could be used for probiotics. Time to time there is need to update microbial flora and follow the research and the published data regarding probiotics to gain more knowledge and ideas (Amara and Shibl, 2015). According to the Ilya Ilyich Metchnikoff postulations, a good probiotics suppress the putrefactive-type fermentation (Metchnikoff, 2004). It significantly improves the intestinal tract health and prevent indigestion problems (Vanderhoof, 2000). *Saccharomyces cerevisiae* was used extensively for treating various diarrheal disorders (Hawrelak, 2003). It reduced lactose intolerance symptoms and improves lactose digestion of foods containing lactose. It decreases the prevalence of allergy in susceptible individuals (Hawrelak, 2003). Probiotics effectively enhance the immune system by synthesizing and enhancing the bioavailability of nutrients (MacFarlane and Cummings, 2002). The use of probiotics influences the protective functions of the intestinal mucosa including the synthesis and secretion of antibacterial peptides (Cammarota *et al.*, 2009). Simultaneously, it reduce the synthetic antibiotic destructive effect and to regenerate any type of loss in beneficial microflora. Some *Bacillus* species are recommended for use with antibiotics while they are resistant to them (Cammarota *et al.*, 2009). Prolong use of probiotics significantly control of serum cholesterol levels; reduce hypertension, reduce the risk of certain cancers (Thirabunyanon *et al.*, 2009), improves the condition of the genitourinary tract (Martinez *et al.*, 2009).

Role of probiotics in digestion

The intestinal microflora is a main barrier against invading and colonizing exogenous pathogens (Forchielli and Walker, 2005). It plays important role in the immune system cell maturation, maintenance of a prolonged and immunologically balanced inflammatory response and development of normal healthy intestinal morphology (Chaplin, 2010).

Several group of microbes are collectively performing diverse function in our body include, crucial role in digestive system; improve food digestion, consumption (Fioramonti *et al.*, 2003). Several diseases are being diagnosed improperly while actual reason behind of this is due to the presence of bad microbes in the digestive system so far continuing the feeding process. So to balance such condition, Probiotics are needed to be given in higher dosages (Reid *et al.*, 2003; Amara and Shibl, 2015). Crucial role of probiotics are to improve digestive system with good microbes that helps to neutralize the harmful strains effects and these microbes will ferment food and it ultimately improve our health (Petrariu *et al.*, 2024).

During day to day life, we are exposed to some bad microbes and which may be unsuitable for the health. Several conditions like high fat diets, meat, high sugar intake, stress, exposure to environmental toxins and so

many others factors may leads to change of our intestinal microbial flora (Hosono *et al.*, 1992). So, to treat these unhealthy condition, the antibiotics treatments are recommended. Unfortunately, this treatment may leads to destroy our useful microbial flora (Amara and Shibl, 2015). If microflora has been affected severely due to any reasons, probiotics given in large dosages form such as tablets or in any other suitable forms (Reid *et al.*, 2003).

Probiotics mechanism of health improvement

Probiotics, involved in the maintenance of normal healthy intestinal microflora by producing various essential metabolites, detoxify colonic contents, promote lactose tolerance, lowers serum cholesterol levels and effectively modulate the immune system (Teitelbaum and Walker, 2002; Boyle *et al.*, 2006). A good probiotics includes certain characters, *i.e.* (i) they have resistance to bile toxicity and gastric acidity, (ii) have ability to adhere to gut epithelial tissue; (iii) production of antimicrobial substances; (iv) ability to colonize the gastrointestinal tract; (v) ability to modulate immune responses and ability to influence metabolic activities (Lacroix and Yildirim, 2007). Various reports are available regarding beneficial use of probiotics on human cells lines and pathogens (Cammarota *et al.*, 2009). The gut microbiome plays various roles in the epithelial barrier maintenance, protection against pathogen colonization and modulation of immune activity (Sucheta *et al.*, 2018). It supposed to exhibit a diversity of mechanisms such as cellular adhesion and antagonism, signaling pathway modification and metabolic regulation, pathogen competition, antitoxin effects, mucin production, immune system regulation, modulation of the normal microbiome, physiological protection, interactions with the brain-gut axis, trophic and nutritional effects (Plaza-Diaz *et al.*, 2019).

Colonizing probiotics bacteria communicate with the underlying epithelium layer. This leads to the immunological and/ or metabolic reaction by epithelial as well as lymphoid cells. Pattern recognition receptors (PRRs) are molecules associated with the innate immune response and its stimulate the subsequent adaptive response nature. One of such PRR is Toll-like receptors (TLRs). Each mammalian TLR specifically recognizes conserved pathogen motifs (Rezaei, 2006) and activate several different signaling elements (Akira *et al.*, 2006). These TLRs are involved in first-line host defense. The cells involved in this mechanism are epithelial cells derived from gut or lungs, B and T lymphocytes, neutrophils, macrophages and dermal endothelial cells (Visintin *et al.*, 2001). Some probiotic strains have ability to eliminate or reduce possibly pathogenic microorganisms by competing for receptor for intestinal mucosa receptor with pathogens and antimicrobial compound synthesis (Puertollano *et al.*, 2018). Fig 2 represents the mechanism of action of probiotics.

Production of short-chain fatty acids (SCFAs) are increased by probiotics and this intern activated by peroxisome-activated proliferator bindings. These SCFAs inhibits enzyme reaction in liver results in inhibition of

cholesterol synthesis and absorption in the intestine (Romero-Luna *et al.*, 2021). *Lactobacillus sp.* probiotics has protease-sensitive receptors that bind tightly to exogenous cholesterol and incorporate them into their cell membrane (Minj *et al.*, 2021). They have strong interaction with cholesterol through their cell wall proteins and exopolysaccharides which effectively remove excess of cholesterol (Angelin and Kavitha, 2020).

Some probiotics produce lipase enzymes which convert saturated fat into healthy unsaturated fatty acids (USFAs) (Ostadzadeh *et al.*, 2022). Bacteria present in the dairy product removes cholesterol through their cell wall adsorption (Sharma *et al.*, 2021). *L. acidophilus*, *Lactocasei bacillus casei* ATCC 393 and *L. bulgaricus*, produce cholesterol reductase enzyme, which reduces cholesterol to coprostanol. Coprostanol is absorbed poorly in the intestine and it expelled out as feces (Romero-Luna *et al.*, 2021). A few probiotics support to bile salt hydrolase enzymes production in the gut. It is involved in the cholesterol breakdown by hydrolyzing conjugated bile acids. This process releases free primary bile acids (e.g., cholic acid and chenodeoxycholic acid) that are hardly reabsorbed by the intestines and excreted in feces, resulting in decreased serum cholesterol levels (Romero-Luna *et al.*, 2021).

Recent advancement in the probiotics with respect to cholesterol lowering

Encouragingly, new-generation fermentation technology and better strains screening make it possible to discover even more effective probiotic candidates that reduce cholesterol. For example, *Lactobacillus plantarum* and *Bifidobacterium lactis* are studied for their cholesterol binding capacity in the intestines and potential dietary cholesterol absorption reduction. Furthermore, some recent studies suggest potential multi-probiotic treatment capabilities. Apart from strain selection, understanding the application of prebiotic and probiotic combinations is

becoming vital. Specifically, prebiotics that are able to stimulate the proliferation of probiotics with cholesterol-lowering abilities may reduce the cholesterol level further. Gut microbes ferment prebiotics and SCFAs are created which have a known beneficial effect on cholesterol metabolism (Pato *et al.*, 2025).

Number of enzymes possesses lipolytic activity and it is one of the important activities. Generally, bacterial lipase is an extracellular enzyme and active outside cell (Jaeger *et al.*, 1994). Some of the examples of lipase containing microorganisms are *Staphylococcus epidermidis*, *Acinetobacter calcoaceticus*, *Staphylococcus aureus* and *Staphylococcus hyicus ssp. Hyicus*. Some of these organism, viz. *S. hyicus ssp. hyicus* and *S. aureus* also possess metallocysteine protease. All above mentioned organisms are isolated from the food and effectively used as a probiotics for cholesterol lowering (Pratuangdejkul and Dharmstithi, 2000).

The most recent meta-analyses of randomized controlled trials corroborate these observations and indicate that probiotics can induce significant lowering of TC and LDL levels. Nonetheless, considerable heterogeneity in terms of study design, specific strains applied and responses toward probiotic therapy indicates that this form of treatment ought to be tailored to each individual. They have been progress in the utilization of probiotics for cholesterol management as they brings favorable changes in lipid metabolism. A number of studies have considered certain probiotic strains, which have the potential to alter the lipid profile. For instance: *Lactobacillus reuteri* NCIMB 30242 was able to demonstrate such promise that clinical participants were able to observe reductions in lower LDL cholesterol levels *via* bile salt hydrolase activity which assists in converting bile acids to their non-reabsorbed form and enhancing their excretion in the feces.

With the advances in fermentation technology and strain selection, many new probiotic candidates exhibiting

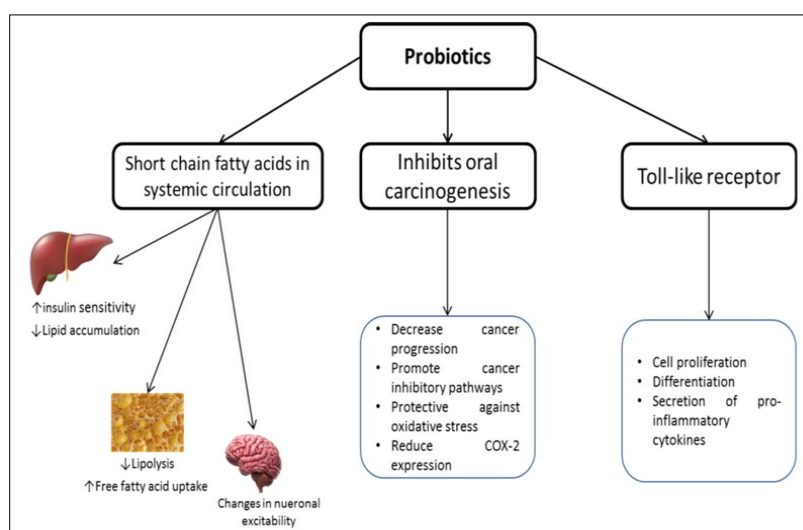


Fig 2: Probiotics mechanism.

enhanced cholesterol-lowering properties have already been identified. Different strains such as *Lactobacillus plantarum* and *Bifidobacterium lactis* are being investigated for their capacity to bind cholesterol in the gut, thereby limiting its absorption. Other recent studies have pointed out the synergistic effects of combinations of probiotics; co-administration of multiple strains might yield greater outcomes than a single-probiotic strain. Regulatory agencies also endorsed probiotics for the management of cholesterol. Authorization of select probiotic products as functional foods has opened avenues for their use in dietary interventions aimed at cardiovascular risk reduction.

The advances in probiotic research on cholesterol-lowering could yield good findings and signify the promise of integrating such microbes in preventive health strategies. There remain ample challenges to elate; as more mechanisms for the effects of probiotics are elucidated and optimal strains and formulations are identified, probiotics may become essential to through-walkers on the stage of the management of dyslipidemia and cardiovascular health, respectively. These will inevitably require ferocious research attention, primarily around establishing guidelines for probiotic application and assigning farther effects on the long-term lipid profiles and heart health.

Pre-clinical and clinical studies on cholesterol lowering drugs

Pre-clinical studies

Numbers of studies are reported for use of probiotics against various disease conditions (Fietto *et al.*, 2004; Edwards-Ingaram *et al.*, 2007; Kabluchko *et al.*, 2017; Rau *et al.*, 2024). Kabluchko *et al.*, (2017) reported in vitro viability testing of *S. boulardii* and bacterial probiotics (*Lactobacillus spp.* and *Bifidobacterium spp.*) probiotic formulation in the GI tract and intestinal environment. *S. boulardii* were able to survive in this harsh environment of stomach. However, bacterial probiotics viability was severely impaired. Fietto *et al.*, (2004) compared the viability of *S. cerevisiae* and *S. boulardii* in the intestinal environment. *S. boulardii* was found to be more sensitive towards the intestinal environment (presence of pepsin, sodium chloride and pancreatin, pH 8.0) than *S. cerevisiae*. Similar findings were reported by the Edwards-Ingaram *et al.*, (2007). Cammarota *et al.*, (2009) studied *Lactobacillus plantarum* DSMZ 12028 probiotic against *E. coli* K4 in vitro. *E. coli* K4 pathogen induced cell death and the intestinal epithelial cell proliferation is not affected by *L. plantarum*. The treatment was effectively down-regulated TLR expression as compare to standard (*L. paracasei*) and negative control. The *E. coli* K4 showed increase in the proinflammatory cytokines. Puertollano *et al.*, (2018) studied molecular effects induced by *L. plantarum*. The results were compared to the alterations generated by the pathogen *E. coli* K4 and a certified probiotic *L. paracasei* F19. As these literature reveals, there is need to improve the specific characters in strains so that it can be used as a probiotics.

Clinical studies

Various studies on probiotics therapy were reported from many countries such as Iran and Perth (Arabi *et al.*, 2022), Australia (Arabi *et al.*, 2022), Germany (Tom-Dieck *et al.*, 2021), China (He and Shi, 2017; Pan *et al.*, 2021), USA and Shanghai (Dong *et al.*, 2019), Italy (Cicero *et al.*, 2021), Brazil (Bernini *et al.*, 2016), etc. He and Shi, (2017) conducted an observational study about the use of various probiotics on the lipid abnormality. Amendment of microencapsulated bile salt hydrolase-active *Lactobacillus reuteri* NCIMB 30242, *Bifidobacterium lactis* and *L. acidophilus* bacteria in the yogurt showed significant reduction in the LDL-cholesterol and total cholesterol (TC). The results were comparable with the consumption of fermented milk containing *L. acidophilus* L1 and a probiotic mixture comprised of *Saccharomyces*, *Bacillus*, *Lactobacillus*, *Streptococcus*, *Clostridium* and *Candida*.

Pan *et al.* (2021) reported reduction in the TC and LDL cholesterol with simultaneous increase in HDL cholesterol, in China. Tom-Dieck *et al.* (2021) did the traditional review for probiotic therapy in Germany. The probiotic capsules consist of *Bacillus subtilis*, L-alanyl-L-glutamine, curcuma extract, green tea extract, zinc (5 mg), vitamin B6, D-biotin, vitamin B12, vitamin D, pantothenic acid were given for four weeks and showed reductions of TC and LDL levels. Dong *et al.*, (2019) studied USA and Shanghai population and reported systematic meta-analysis review on probiotic foods or supplements and reported decrease in LDL level.

Arabi *et al.* (2022) reported that the probiotic therapy reduces serum LDL and increase HDL levels in Australia population. The lowering was higher than minimal clinically important difference, which is important for clinicians to reach treatment goals. Cicero *et al.* (2021) conducted randomised controlled trial for probiotic formula (*L. Plantarum* PBS067-DSM 24,937, *L. acidophilus* PBS066-DSM 24,936 and *L. reuteri* PBS072) for the period of two months. This formula significantly decreased LDL, TC and triglycerides with increase in HDL level. It also decreased metabolic syndrome prevalence, several cardiovascular risk factors and markers of insulin resistance. Bernini *et al.* (2016) performed a randomized controlled trial on fermented milk with probiotics intervention for 45 days. However, no significant differences were observed intra- or intergroup for triglycerides (TGs) and HDL.

CONCLUSION

The current available drugs have some side effect and they are means for therapeutic use. The probiotics can be incorporate in daily healthy lifestyle as they have ability to act as a prophylactic agent against various disease conditions. The role of gut microbiome in the gastrointestinal (GI) disorders pathogenesis is now a developing area of research. It's become more important to understand the crosstalk between gut epithelia and microorganism. The diet significantly alters the composition and function of the microbiome. It has been challenging to develop precise public guidelines for these dietary supplements because

of the considerable variation in strains, dosages and treatment length examined in various research, as well as safety issues with delivering live organisms.

ACKNOWLEDGEMENT

The authors would like to thank Symbiosis International (Deemed University) (SIU), Pune for infrastructural support. The author, MB, gratefully acknowledges SIU for providing a PhD scholarship.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest.

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